Claims

[c1] An NMR measurement apparatus, comprising:
a permanent magnet;
a primary coil extending across a first surface area, the primary coil having an associated depth of investigation and an associated vertical resolution and producing a primary RF field in a volume of earth formation;
a secondary coil extending across a second surface area, the second surface area less than the first surface area, the secondary coil having an associated depth of investigation and an associated vertical resolution and producing a secondary RF field in a volume of earth formation;
a circuit coupled to the primary coil and the secondary coil adapted to perform high resolution NMR measurements of an earth formation.

[c2] The NMR measurement apparatus of claim 1, wherein the NMR measurements comprise a secondary coil dataset associated with NMR measurements made for a depth of investigation associated with the secondary coil.

[c3] The NMR measurement apparatus of claim 2, wherein a high resolution log is generated based on the secondary coil dataset.

[c4] The NMR measurement apparatus of claim 2, wherein the NMR measurements further comprising a primary coil dataset associated with NMR measurements made for a depth of investigation associated with the primary coil.

[c5] The NMR measurement apparatus of claims 4, wherein a spin-spin relaxation estimate based on a combination of the primary coil dataset and the secondary coil dataset.

[c6] The NMR measurement apparatus of claim 1, wherein the depth of investigation of the secondary coil is shallower than a depth of investigation of the primary coil.

[c7] The NMR measurement apparatus of claim 1, wherein the depth of investigation of the secondary coil is substantially the same depth as the depth of investigation of the primary coil.

[c8] The NMR measurement apparatus of claim 1, wherein the NMR measurement apparatus is a centralized-type logging tool.

[c9] The NMR measurement apparatus of claim 1, wherein the secondary RF field is orthogonal to the primary RF field.

[c10] The NMR measurement apparatus of claim 1, wherein a size of the secondary coil is optimized based on a combination of the depth of investigation of the secondary coil and the primary coil and the vertical resolution of the secondary coil and the primary coil.

[c11] The NMR measurement apparatus of claim 1, wherein the NMR measurements are made while drilling a borehole.

[c12] The NMR measurement apparatus of claim 1, wherein the primary coil and the secondary coil are arranged in a non-overlapping configuration along the axis of the apparatus.

[c13] The NMR measurement apparatus of claim 12, wherein the secondary antenna is located near a proximate end of the main antenna measured along the longitudinal axis of the NMR measurement apparatus.

[c14] The NMR measurement apparatus of claim 12, wherein the secondary coil is located a distance from the primary coil that minimizes an electrical coupling between the secondary coil and the primary coil.

[c15] The NMR measurement apparatus of claim 12, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

[c16] The NMR measurement apparatus of claim 15, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence.

[c17] The NMR measurement apparatus of claim 15, wherein the primary coil is selectably operated in either a passive or active mode.

[c18] The NMR measurement apparatus of claim 1, wherein at least a portion of the first surface area overlaps the second surface area.

[c19] The NMR measurement apparatus of claim 1, wherein the secondary antenna is embedded in the primary antenna.

[c20] The NMR measurement apparatus of claim 19, wherein the second coil is operated in a passive mode as a receiver of signals produced in response to a transmission by the first coil.

[c21] The NMR measurement apparatus of claim 19, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

[c22] The NMR measurement apparatus of claim 21, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence.

[c23] The NMR measurement apparatus of claim 21, wherein the primary coil is selectably operated in either a passive or active mode.

[c24] The NMR measurement apparatus of claim 1, the secondary coil further comprising:
an array of secondary coils arranged in a non-overlapping configuration along the axis of the apparatus.

[c25] The NMR measurement apparatus of claim 24, wherein the array of the secondary coils comprises a pair of secondary coils, each of the pair of secondary coils situated at opposite proximate ends of the primary coil measured along the longitudinal axis of the NMR apparatus.

[c26]
A method for obtaining high-resolution NMR measurements of an earth formation from an NMR apparatus having a magnet, a primary coil and at least one secondary coil, the method comprising steps of:
producing a static magnetic field in the earth formation with the magnet;
transmitting at least a portion of an RF pulse sequence with the primary coil extending across a first surface area to produce an oscillating magnetic field that is substantially orthogonal to the static magnetic field;
receiving NMR signals with the secondary coil extending across a second surface area, the second surface area less than the first surface area; and
calculating at least one high resolution measurement based on the received

NMR signals.

[c27] The method of claim 26, further comprising:
generating a secondary coil dataset associated with NMR measurements made for a depth of investigation associated with the secondary coil .

[c28] The method of claim 27, further comprising:
generating a high resolution log is based on the secondary coil dataset.

[c29] The method of claim 27, further comprising:
receiving NMR signals with the primary coil;
generating primary coil dataset associated with NMR signals from a depth of investigation associated with the primary coil.

[c30] The method of claim 29, further comprising:
calculating a spin-spin relaxation estimate based on a combination of the primary coil dataset and the secondary coil dataset.

[c31] The method of claim 26, wherein the depth of investigation of the secondary coil is shallower than a depth of investigation of the primary coil.

[c32] The method of claim 26, wherein the depth of investigation of the secondary coil is substantially the same depth as the depth of investigation of the primary coil.

[c33] The method of claim 26, wherein the NMR measurement apparatus is a centralized-type logging tool.

[c34] The method of claim 26, wherein the secondary RF field is orthogonal to the primary RF field.

[c35] The method of claim 26, further comprising the step of:
optimizing the size of the secondary based on a combination of the depth of investigation of the secondary coil and the primary coil and the vertical resolution of the secondary coil and the primary coil.

[c36] The method of claim 26, the calculating step further comprising calculating the high resolution measurement while drilling a borehole.

[c37] The method of claim 26, wherein the primary coil and the secondary coil are arranged in a non-overlapping configuration along the axis of the apparatus.

[c38] The method of claim 37, wherein the secondary antenna is located near a proximate end of the main antenna measured along the longitudinal axis of the NMR measurement apparatus.

[c39] The method of claim 37, wherein the secondary coil is located a distance from the primary coil that minimizes an electrical coupling between the secondary coil and the primary coil.

[c40] The method of claim 37, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

[c41] The method of claim 40, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence.

[c42] The method of claim 40, wherein the primary coil is selectably operated in either a passive or active mode.

[c43] The method of claim 26, wherein at least a portion of the first surface area overlaps the second surface area.

[c44] The method of claim 26, wherein the secondary antenna is embedded in the primary antenna.

[c45] The method of claim 44, wherein the second coil is operated in a passive mode as a receiver of signals produced in response to a transmission by the first coil.

[c46] The method of claim 44, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

[c47] The method of claim 46, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence.

[c48] The method of claim 46, wherein the primary coil is selectably operated in either a passive or active mode.

[c49] The method of claim 26, the secondary coil further comprising:

an array of secondary coils arranged in a non-overlapping configuration along the axis of the apparatus.

[c50] The method of claim 49, wherein the array of the secondary coils comprises a pair of secondary coils, each of the pair of secondary coils situated at opposite proximate ends of the primary coil measured along the longitudinal axis of the NMR apparatus.

[c51] The method of claim 49, the array of secondary coils further comprising:
a first plurality of secondary coils having a radiation polarization orthogonal to a radiation polarization of the primary coil; and
a second plurality of secondary coils having a radiation polarization parallel to the radiation polarization of the primary coil, wherein the secondary coils of the first plurality are alternated with the secondary coils of the second plurality.

[c52] An NMR measurement apparatus, comprising:
a permanent magnet;
an array of coils situated along a longitudinal axis of the apparatus;
a circuit coupled to the array of coils adapted to perform high resolution NMR measurements of an earth formation.

[c53] The NMR measurement apparatus of claim 52, wherein at least two coils of the array of coils have different pre-polarizations times.

[c54] The NMR measurement apparatus of claim 52, wherein a spin-lattice relaxation estimate based on a combination spin echo measurements from at least two of the array of coils.

[c55] The NMR measurement apparatus of claim 52, wherein at least one coil of the array of coils is operated in an active mode as both a transmitter and a receiver.

[c56] The NMR measurement apparatus of claim 55, wherein at least one of the active coils transmits a portion of an NMR acquisition sequence.

[c57] The NMR measurement apparatus of claim 55, wherein at least one coil of the array is selectably operated in either a passive or active mode.

[c58] The NMR measurement apparatus of claim 52, the array of coils further comprising:
A first plurality of coils;
A second plurality of coils having a radiation polarization orthogonal to a radiation polarization of the first plurality of coils, wherein the coils of the first plurality are alternated with the coils of the second plurality.

[c59] The NMR measurement apparatus of claim 52, the array of coils comprising:
a primary coil extending across a first surface area, the primary coil having an associated depth of investigation and an associated vertical resolution and producing an RF field in a volume of earth formation;
a plurality of secondary coils, each secondary coil extending across a second surface area, the second surface area less than the first surface area, the secondary coil for receiving spin echoes from a volume of an earth formation at a depth of investigation associated with the secondary coil.

[c60] The NMR measurement apparatus of claim 59, wherein the plurality the secondary coils comprises a pair of secondary coils, each of the pair of secondary coils situated at opposite proximate ends of the magnet measured along the longitudinal axis of the NMR measurement apparatus.

[c61] The NMR measurement apparatus of claim 60, wherein the primary coil is situated between a pair of secondary coils.

[c62] The NMR measurement apparatus of claim 60, wherein the each coil of the pair of secondary coils has a different pre-polarization time.